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OPTIMIZATION OF MICRO HARDNESS OF FINISHED SURFACE IN SPARK ASSISTED ABRASIVE FLOW MACHINING

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ABSTRACT

Finishing is the prime requirement for the better functional performance and longer life cycle of the product. A single scratch over the surface may cause the failure of the component. This required development of such a process, which can provide better surface finish to the complex geometries, economically. Abrasive Flow Machining is a non conventional technique used for the finishing of critical shaped geometries, which cannot be obtained through the conventional techniques. Spark assisted Abrasive Flow Machining is the hybrid form of Abrasive Flow Machining which enhances the micro hardness of the finished surface and providing better strength to the component. The present paper used L_9 OA for the optimization of the micro hardness of surface finished through spark assisted Abrasive Flow Machining. The effect of parameters such as current, duty cycle and extrusion pressure was studied for the micro hardness of finished surface.

KEYWORDS: Spark, Finishing & Micro Hardness

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Original Article

INTRODUCTION

Abrasive Flow Machining (AFM) is a non conventional finishing process used to finish the complex geometries which cannot be obtained through the conventional finishing techniques [1]. The conventional techniques such as lapping, honing, grinding etc. are very slow and cannot be used to finish complex structures because it uses a rigid tool for the finishing. In Abrasive Flow Machining material is removed through the flexible tool i. e. sharp cutting edge abrasive particles. It uses a non Newtonian media as an abrasive carrier and is a combination of polymer, gel abrasive. This type of mixture is called as abrasive laden media [2]. The material is removed through abrasion mechanism in AFM process. The material is removed in the form of micro and nano chips. This technique removes the layer thickness in the range of 1 to 10 μm and can achieve the $R_a$in the range of 50 nm [3]. AFM technique reduces 90 percent of finishing time in comparison to the conventional technique [4]. Sidhu et al. [5] finished EDM generated surface through AFM process and studied about recast layer on the surface using SEM micrographs. From the experimental result showed that the micro hardness and surface properties were improved through the increase in the density of reinforced particles. Tzeng et al. [6] finished an EDM generated micro channel using self modulating abrasive media in AFM technique and found that, coarse abrasive particle provide better finishing in comparison to the fine abrasive particles. Walia et al. [7] developed CFAAFM process using CFG rod in the media flow path. This caused generation of centrifugal force in the media flow path, which increased the dynamic number of abrasive particles.

Sankar et al. [8] used a drill bit in the media flow path, which caused the media to flow through the flutes

of the drill. This type of media corresponded better intermixing of the media and increased the contact between the abrasive particles and the workpiece surface. Marzban et al. [9] provided spin motion to the workpiece along with the rotational motion of the workpiece. The researcher observed significant improvement in the material removal. Chen et al. [10] proposed different types of passageways in the media flow path and found that the helical passageways provided better material removal in comparison to the polygonal passageways. Das et al. [11] finished stainless steel workpiece using Rotational magneto rheological process and found 2.04 µm improvement in out of roundness.

PRINCIPLE AND EXPERIMENTAL SET UP

This process is a combination of Centrifugal force assisted AFM and EDM mechanism. In this process, spark is developed between the rotating electrode and the workpiece through EDM mechanism. The workpiece is given as positive supply, and rotating electrode is given as negative supply. The gap between both the electrode is taken as minimum to produce the spark. Whenever the potential difference is applied between the two poles, spark is developed on the surface. The spark produced a high temperature over the surface and melted the surface material. This melted material is easily carried away by the abrasive particles. Figure 1 shows the experimental set up of Spark assisted Abrasive Flow Machining Process.

The experimental setup of Spark assisted Abrasive Flow machining consisted 3 phase induction motor, EDM power supply, EDM Control Panel, Power drive, bearings, gears, fixture etc. The fixture was made of Nylon and had two functions. It supported the workpiece during the media flow path and guided the media between media cylinders. The fixture consist the rotating electrode, gears to produce the centrifugal effect and power supply terminals for power supply.

The function of the EDM power supply is to convert the AC supply to pulsed DC supply and senses the potential difference between both the poles. It also helps the Controller to sense the gap between the rotating electrode and the wok piece surface. Whenever the gap is being maintained between both the poles, spark was produced on the inner cavity of the surface. The function of the power drive is to control the rotational speed of the electrode. The gears are used to rotate the electrode inside the cavity of hollow workpiece to produce uniformity on the surface.

(a) Experimental Arrangement of Spark Assisted Abrasive Flow Machining

(b) Arrangement of Media Cylinder and Fixture

Figure 1: Experimental setup of Spark Assisted Abrasive Flow Machining

SELECTION OF TEST PIECE

The length and diameter of the test piece was selected as per the geometry given in the figure 2. The material selected for the workpiece was Brass. The inner surface of the hollow work piece was finished by AFM process. Each workpiece was finished for 5 numbers of cycles.

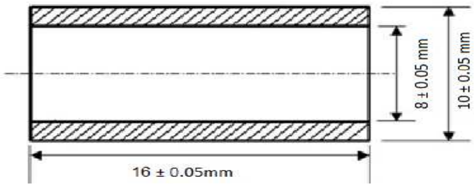


Figure 2: Geometry of Test Piece

RESPONSE CHARACTERISTICS

The effect of process parameters (Current, Duty cycle and Extrusion Pressure) were studied for the response i. e. Micro Hardness, in Spark assisted Abrasive Flow Machining.

Micro hardness was measured through the FISCHERSCOPE Micro Hardness Tester HM2000S on the inner surface of the workpiece. For each workpiece, three times micro hardness was measured and average of these was considered as the final value.

Figure 3: Micro Hardness Tester

SCHEME OF EXPERIMENTS

The experiments were performed to analyze the effect of some of the important AFM variables on Micro hardness of surface. Taguchi parametric design methodology was used for conducting the experiments on the basis of L_9 orthogonal

array (OA). The selected number of process parameters and their levels are given in the Table 1

Table 1: Process Parameters and their Values at Different Levels

Symbol	Process Parameters	Unit	L1	L2	L3
I	Current	Amp	3	6	9
D	Duty Cycle	Fraction	0.68	0.73	0.78
P	Extrusion Pressure	MPa	10	20	30

EXPERIMENTATION

The three process parameters, Current, Duty Cycle, and Extrusion Pressure were selected according to the table 1. Each experiment was repeated for three times for each of the trial conditions. Thus, twenty seven work-pieces were selected for experimentation. For each trial conditions and every replication, micro Hardness were measured and recorded in Table 2.

Table 2: Experimental Results of Various Response Characteristics

E. N.	R. O.	Micro Hardness			S/N ratio (db)
		R1	R2	R3	
1	1	239.4	245.12	255.17	18.09
2	4	216.34	231.13	235.47	24.60
3	7	189.93	256.57	248.76	24.05
4	2	254.33	261.24	258.46	24.69
5	5	315.78	304.36	292.35	29.78
6	8	378.45	388.35	344.35	27.51
7	3	245.46	353.24	321.12	20.20
8	6	398.74	413.34	385.44	22.92
9	9	328.47	342.23	351.23	23.39
Total		2566.9	2795.58	2692.35	
		$\bar{T}$ = Overall mean of Micro Hardness = 298.33			

RESULTS AND DISCUSSION

The micro Hardness for each trial condition was measured and recorded in Table 2. Higher and better quality characteristic was taken for the response and for calculating S/N ratio.

$$(S/N)_{HB} = -10 \log[\frac{1}{n} \sum_{j=1}^{R} \frac{1}{Y_j^2}]$$

Analysis and Discussion of Results

The analysis of variance (ANOVA) has been performed to determine the significant parameters and their effect on Micro Hardness of finish surface.

Effect on Micro Hardness

The average values of Micro Hardness and S/N ratio for every parameter at levels L1, L2 and L3 are calculated and given in table 3.

Table 3: Average Values and Main Effects: Micro Hardness (HV)

Process Parameter	Level	Current (I)		Duty Cycle (D)		Extrusion Pressure (P)	
Type of Data		Raw Data	S/N Ratio	Raw Data	S/N Ratio	Type of Data	Raw Data
Average Values(%Ra)	L1	235.32	47.33	270.39	48.49	338.70	50.39
	L2	310.85	49.73	310.32	49.59	275.43	48.66
	L3	348.80	50.68	314.26	49.67	280.84	48.70
Main Effects(%Ra)	L2-L1	75.53	2.40	39.93	1.10	-63.27	-1.72
	L3-L2	37.95	0.94	3.93	0.08	5.40	0.04
Difference (L3-L2)–(L2-L1)		-37.57	-37.57	-1.45	-37.57	-1.02	68.68

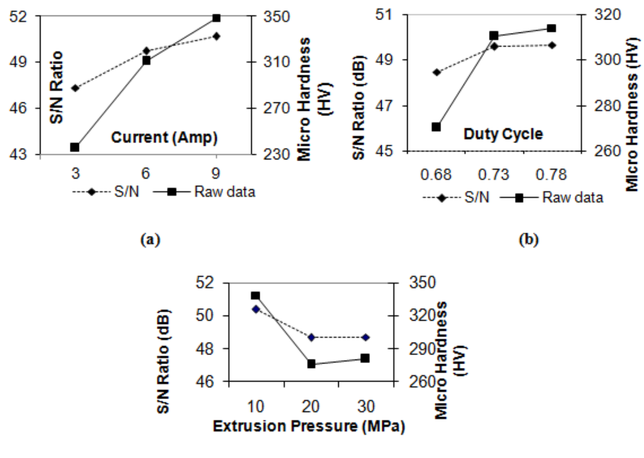
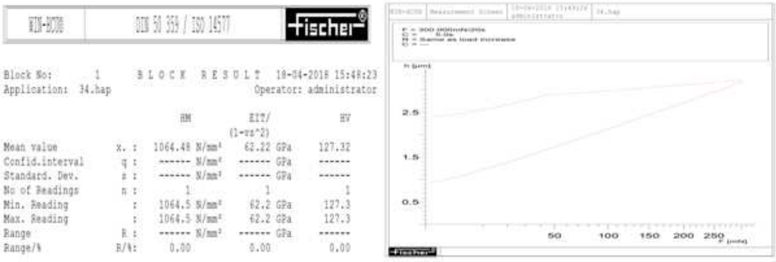


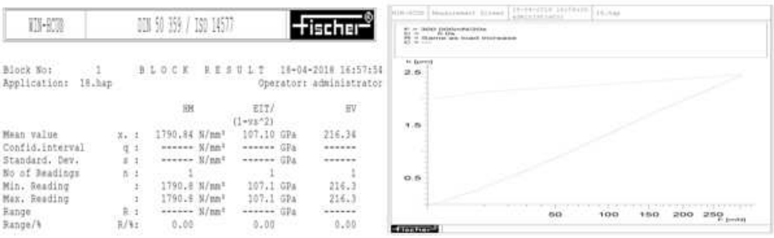
Figure 4: Effect of Parameters on Micro Hardness of the Finished Surface

Figure 4 (a) showed increase in Micro hardness with the current intensity. As the value of current increased, energy density was enhanced and developed more temperature over the surface. This caused better heating and quenching of material. This heating and quenching formed hard carbide over the surface and increased the micro hardness. The effect of current intensity over the micro hardness of finished surface can be seen through figure 5.

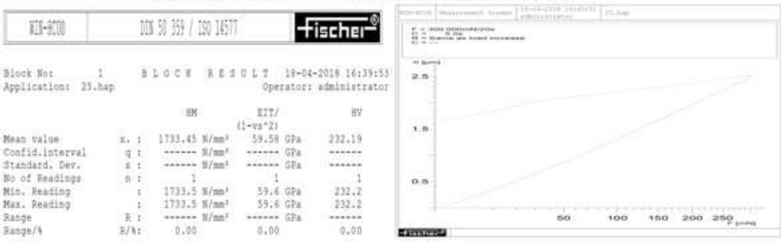
Figure 4(b) showed increase in Micro hardness with duty cycle. As the value of duty cycle was increased, energy will be concentrated for a longer duration which melted more material from the surface and increased the micro hardness of the surface. Figure 4(c) shows initial decrease and further increase in micro hardness with the extrusion pressure. On initially increasing the extrusion pressure, there is a chance that some abrasive particles could not contact with the surface which caused decrease in micro hardness, but on further increasing the extrusion pressure, more number of abrasive particles will come in contact with the workpiece and cause strain hardening of surface. This increased the micro hardness of the surface.



(a) Micro hardness of finished surface at 3 Ampere Current



(b) Micro hardness of finished surface at 6 Ampere Current



(c)Micro hardness of finished surface at 9 Ampere Current

Figure 5: Effect of Current Intensity on the Micro Hardness

SELECTION OF OPTIMUM LEVELS

The pooled versions of ANOVA for both raw data and the S/N data for Micro Hardness are given in Tables 4&5.

Table 4: Pooled ANOVA for Raw Data (Micro Hardness)

S	S. S	D. O. F	V	F-Ratio	SS'	P%
Current	60074.38	2	30037.19	53.32	58947.73	57.71
Duty Cycle	10603.52	2	5301.76	9.41	9476.86	10.18
Pressure	22143.54	2	11071.77	19.65	21016.89	21.27
e	11266.55	20	563.32	------	14646.52	10.82
Total (T)	104088.01	26	*	-------	104088	100

Table 5: Pooled ANOVA for S/N Data (Micro Hardness)

S	S. S	D. O. F	V	F-Ratio	SS'	P%
Current	17.89	2	8.94	152.72	17.77	67.59
Duty cycle	2.62	2	1.31	22.43	2.51	9.93
Pressure	5.82	2	2.91	49.76	5.71	22.02
e	0.11	2	0.05	------	0.46	0.44
Total (T)	26.46	8	--------	-------	26.46	100

Estimation of Optimum Response Characteristics for Micro Hardness

The optimal Micro Hardness is estimated as

$$\mu = \bar{I}_3 + \bar{D}_3 + P_1 - 2\bar{T} \quad (1)$$

$\bar{T}$= overall mean of the response = 298.33 HV

$\bar{I}_3$ =Mean value of Micro Hardness at the Third level of Current = 348.80 HV

D_3 =Mean value of Micro Hardness at the third level of Duty Cycle= 314.26 HV

$\bar{P}_1$ =Mean value of Micro Hardness at the first level of Extrusion Pressure = 338.70 HV

Substituting these values, Mean Micro Hardness = 405.1 HV

The confidence interval of confirmation experiments (CI_{CE}) and (CI_{POP}) can be determined by the following equation

$$CI_{CE} = \sqrt{F_a(1, f_e)V_e\left[\frac{1}{n_{eff}} + \frac{1}{R}\right]} \quad (2)$$

$$CI_{POP} = \sqrt{\frac{F_a(1, f_e)V_e}{n_{eff}}} \quad (3)$$

Where $F_\alpha(1, f_e)$ = = 3.49(Tabulated Value),((f_e = Error D. O. F = 20, N = Total number of experiments =27, R = Sample size = 3, V_e = Error variance =563.33

$$n_{eff} = \frac{N}{1+[\text{DOF associated in the estimate of mean responce}]} = 3.86$$

So, CI_{CE} = ± 34.03 and CI_{POP} = ± 22.57

The 95% confirmation interval for the predicted optimal range is:

Mean Micro Hardness – CI_{CE}<Micro Hardness >Micro Hardness + CI_{CE}= 371.07< MR <439.13

The 95% confirmation interval for the predicted mean is :

Mean Micro Hardness – CI_{POP}< Micro Hardness > Micro Hardness + CI_{POP}= 382.53< Micro Hardness <427.67

Confirmation Experiments

For the maximum Micro hardness, the optimal levels of the process parameter are $I_3D_3P_1$.

I_3 = Current at third level = 9 Amp

D_3 = Duty Cycle at third level = 0.78

P_1 = Amount of Pressure at first level =10 MPa

The values for the Micro hardness obtained through the confirmation experiments are within the confidence interval and is recorded in Table 6

Table 6: Predicted Optimal Values and Confidence Intervals for the Confirmation Experiments

Response Characteristic	Optimal Process Parameters	Predicted Optimal Value	Confidence Intervals 95%	Actual Value(Avg of Confirmation Exp)
Micro Hardness	$I_3D_3P_1$	405.1 HV	CI_{CE}371.07:<Micro hardness<439.13HV CI_{POP}: 382.53<Micro hardness<427.67	412.12 HV

CONCLUSIONS

The following conclusions can be drawn on the basis of the above experimental study:

- On increasing the current intensity, Micro hardness of the surface was increased due to hard carbides formation on the surface.
- The micro hardness of the surface was increased with the duty cycle, due to increase in the frequency of the spark.
- The 95 % confidence interval for the Micro hardness was 371.07:HV<Micro Hardness <439.13HV.
- The percentage contribution of the parameters as current, duty cycle and pressure was 57.71%, 10.18% and 21.27%, respectively.
- Current was the most significant parameter towards the Micro hardness of finished surface.

REFERENCES

1. *Brar, B. S; Walia, R. S;& Singh, V. P. (2010). State of Art Abrasive Flow Machining. National Conf. on Adv. and Futur. Trends in Mech. and Matrls. Engg. (AFTMME' 10), Yadavindra College of Engg. Talwandi Sabo, Distt. Bathinda, Punjab, India.*
2. *Rhoades, L. J.(1987). Abrasive flow machining with not-sosilly putty. Met Finish, July 27–29.*
3. *Sankar, M. R;Jain, V. K;& Ramkumar, J. (2008). Abrasive flow machining (AFM): An Overview. INDO-US WORKSHOP on Smart Machine Tools, Intelligent Machining Systems and Multi-scale Manufacturing. December.*
4. *Brar, B S; Walia, R S; Singh, V P; & Sharma, M.(2013). A Robust Helical Abrasive Flow Machining (HLX-AFM) Process. Journal of the Institution of Engineers (India): SeriesC, 94(1), 21-29.*
5. *Sidhu, S S; Batish, A; & Kumar, S.(2014). Study of Surface Properties in Particulate-Reinforced Metal Matrix Composites (MMCs) Using Powder-Mixed Electrical Discharge Machining (EDM). Materials and manufacturing Processes, 29 (1), 495-500.*
6. *Panneerselvam, K., & Lenin, K. (2013). Study on hardness and micro structural characterization of the friction stir welded Nylon 6 plate. Int J Mech Eng, 2, 51-62.*
7. *Tzeng Hsinn, Jyh; Yan Biing, Hwa; Hsu Rong, Tzong; & Lin Yan, Cherng.(2007). Self modulating abrasive medium and its application to abrasive flow machining for finishing microchannel surface. International journal of Advance manufacturing technology, 32, 1163–1169.*
8. *Walia, R S; Shan, H S; & Kumar, P K.(2009). Enhancing AFM process productivity through improved fixturing. International Journal of Advanced Manufacturing Technology, 44, 700-709.*

9. *Sankar, M Ravi; Mondal, S; Ramkumar, J; & Jain, V K.(2009). Experimental Investigations and Modeling of Drill Bit Guided Abrasive Flow Finishing (DBG-AFF) Process. International Journal of Advanced Manufacturing Technology, 42 (7-8), 678-688.*

10. *Marzban, M Ali; & Hemmati, Seyed Jalal.(2017). Modelling of abrasive flow rotary machining process by artificial neural network. International Journal of Advanced Manufacturing Technology, 89, 125–132.*

11. *Mahdi, A. E. A. K. T. Recovery Behavior of Hardness Indentations of Epoxy-Reinforced Hybrid Filler.*

12. *Chen, Kuan Yu; & Cheng, Ken Chuan.(2014). A study of helical passageways applied to polygon holes in abrasive flow machining. International Journal of advanced Manufacturing Technology, 74, 781–790.*

13. *Das, M; Jain, V K; & Ghoshdastidar, P S.(2011). The Out-of-Roundness of the Internal Surfaces of Stainless Steel Tubes Finished by the Rotational–Magnetorheological Abrasive Flow Finishing Process. Materials and manufacturing Processes, 26 (8), 1073-1084.*